Digital Multi-Day Soil Temperatures Protocol

Purpose

To record daily measurements of maximum, and minimum soil temperatures at depths of 5 and 50 cm

Overview

A digital thermometer is used to measure current temperatures as well as daily minimum and maximum temperatures. One temperature probe is placed at a depth of 5 cm in the soil while another is installed at a 50 cm depth. The daily minimum and maximum temperatures are stored by the instrument for a period of up to six days and need to be read and recorded at least this often to avoid loss of data.

Student Outcomes

Students gain insight into the relationships between soil temperatures at two depths over time and learn to use a digital thermometer.

Science Concepts

Geography

- The variability of temperature of a location affects the characterization of Earth's physical geographic system.

Enrichment

- Soil temperature varies with air temperature.
- Soil temperature varies less than air temperature.

Scientific Inquiry Abilities

- Use a digital Max/Min thermometer.
- Identify answerable questions.
- Design and conduct scientific investigations.
- Use appropriate mathematics to analyze data.
- Develop descriptions and explanations using evidence.
- Recognize and analyze alternative explanations.
- Communicate procedures and explanations.

Time

10 minutes per measurement set

Level

All levels

Frequency

At least once every six days

Materials and Tools

- Digital multi-day max/min thermometer
- Instrument Shelter installed on a post
- Digging tools (site setup only)
- Calibration thermometer
- Soil probe thermometer (recalibration only)

Preparation

Set up the instrument shelter.

Review material given in the *Soil Temperature Protocol*.

Prerequisites

None

Digital Multi-Day Soil Temperatures Protocol – Introduction

There are two protocols that utilize the digital multi-day max/min thermometer. This protocol details how to use the thermometer to measure soil temperatures at depths of 5 and 50 cm. The *Digital Multi-Day Max/Min/Current Air and Soil Temperatures Protocol* outlines how to use the thermometer to measure air temperature and soil temperature at a depth of 10 cm. If you purchase two thermometers, both protocols may be done at the same location, and you will be able to measure air temperature along with soil temperatures at three separate depths. This will allow you to construct and study a soil temperature profile.

This protocol is to be done at a Soil Moisture or Atmosphere Study Site. It makes your data more useful if you have this site at the same location as an atmosphere site that features a thermometer measuring air temperature. You may need to define a new soil moisture site specifically for your digital multi-day soil thermometer.

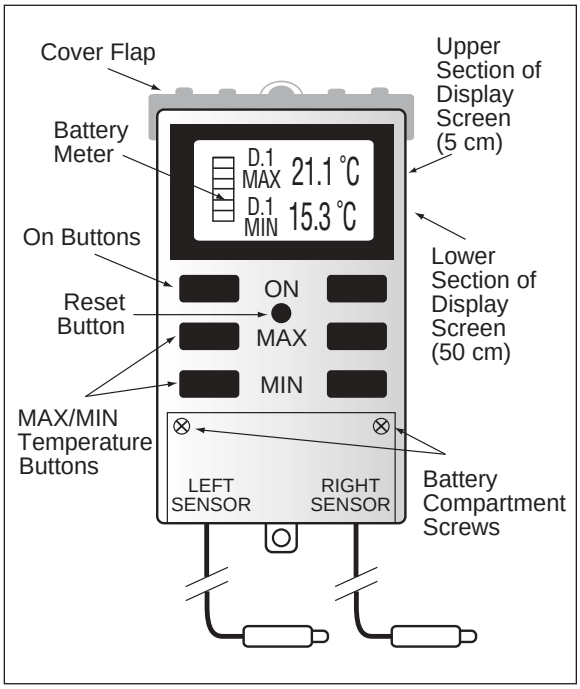
Digital Multi-Day Max/Min Thermometer

The digital multi-day max/min thermometer is an electronic instrument used to measure the current temperature and record the maximum and minimum temperatures reached during multiple 24-hour periods. It has two identical temperature probes.

The instrument records and stores the highest and lowest temperatures reached over six successive 24-hour periods. The start and end times for these periods correspond to the time of day at which the instrument was reset by the user (the *time of reset*). The instrument is reset when it is first setup and again whenever the battery is changed. For use in GLOBE, the reset time must be within one hour of local solar noon. If the reset time is within 15 minutes of local solar noon, all 24-hour periods throughout the year will begin and end within one hour of local solar noon even though the time of local solar noon varies.

The thermometer displays the maximum and minimum temperatures for the current day as well as for the previous five days as long as it is read at a time that is later than the *time of reset*. If the thermometer is read before the *time of reset*, it will display the maximum and minimum temperatures for the previous six days.

Figure SO-MU-1: Digital Multi-Day Max/Min Thermometer



The digital multi-day max/min thermometer is capable of measuring temperatures down to -20°C when run on a standard alkaline AA-size battery. Substitution of a lithium AA-size battery will allow the instrument to handle lower temperatures. Also, at temperatures below zero, the digital display screen may become too dim to read, but the instrument is still recording temperatures. If your students need to read the thermometer they my hold it in their hands to warm it up; this won't affect the thermometer readings as the temperature probes are buried in the ground.

Temperature Probes

In this protocol, one probe of the digital thermometer is used to measure soil temperature at 5 cm depth and the other to measure soil temperature at 50 cm depth. For the sake of consistency the probes should be placed as follows:

Left Sensor – 5 cm depth in soil,

Right Sensor – 50 cm depth in soil.

The display areas for the two sensors are labeled on the right side of the digital display screen for the instrument. The upper display area (which is for the left sensor) is labeled 'LF', while the lower display area (which is for the right sensor) is labeled 'RT'.

Hint: To help prevent confusion, label these display areas as '5 cm' and '50 cm' respectively. This can be done by writing on a piece of tape attached to the left of the display screen.

Instrument Maintenance

The instrument shelter should be kept clean both inside and outside. Dust, debris, and spider webs should be removed from the inside of the shelter with a clean, dry cloth. The outside of the shelter may be lightly washed with water to remove debris, but avoid getting water inside the shelter. If the outside of the shelter becomes very dirty, it should be repainted white.

When the battery in the thermometer becomes low on power a low battery symbol will light. This symbol is located along the left side of the display screen and is shaped like a AA-size battery. Once this symbol becomes visible it is time to replace the battery. Follow the *Changing the Battery in the Digital multi-day Max/Min Thermometer Field Guide*.

Teacher Support

The instructions given in this protocol are specific to one brand of digital thermometer. They may be adapted to other equipment that meets the same specifications. If you have questions or require assistance with adapting these instructions to other instruments, contact the GLOBE Help Desk or your country coordinator. The essential elements of this protocol, which must remain the same regardless of the equipment model, are the placement of the temperature probes, the timing of the 24-hour periods, and the +/- 0.5° C precision and stability of calibration of the temperature sensors.

Measurement Logistics

1. Review background in Soil chapter.
2. Check a calibration thermometer following the *Thermometer Calibration Lab Guide*.
3. Calculate sensor correction offsets following the *Digital Multi-Day Soil Thermometer Sensor Calibration Field Guide*.
4. Install your digital multi-day max/min thermometer following the *Digital Multi-Day Soil Thermometer Installation Field Guide*.
5. Establish your *time of reset* by resetting the thermometer as close to local solar noon as possible following the *Digital Multi-Day Max/Min Thermometer Reset Field Guide.*
6. Record maximum and minimum temperatures following the *Digital Multi-Day Maximum and Minimum Soil Temperatures Field Guide* at least once every six days.
7. Record current temperatures following the *Digital Soil Thermometer Current Temperature Field Guide* as desired.
8. Every six months, or whenever the battery is changed, check the accuracy of the 5 cm soil probe following the *Digital Multi-Day Max/Min Thermometer 5 cm Sensor Error Check Field Guide.* GLOBE will advise you whether you need to dig out your soil sensors and recalibrate them.
9. Engage students in looking at their data.

Calibration

Your digital thermometer must be calibrated before initial use. Every six months after installation and whenever the battery is changed the soil sensor readings will need to be checked to see if the soil sensors need to be dug out and recalibrated. These calibrations and checks are performed by comparing temperatures read by the two probes with readings from a calibration thermometer and the soil probe thermometer (see the *Soil Temperature Protocol*).

Helpful Hints

- The goal of the calibrations is to obtain sensor correction offsets that account for differences between measured and actual temperatures. When you report your calibration data to the GLOBE database, the database automatically calculates these values and reports them to you. After you have completed your calibration and start reporting temperature data to GLOBE, the database will automatically account for your correction offsets as your measurements are entered into the database. So, all the data in the GLOBE database has effectively been calibrated. However, take caution to account for the correction offsets when analyzing data that was not obtained from the GLOBE database (including data that you have collected). DO NOT APPLY THE OFFSETS TO DATA BEFORE REPORTING THEM TO GLOBE.
- There is a battery low indicator on the left side of the display screen. It is shaped like a battery divided into sections (see thermometer diagram). When this indicator lights, it is time to replace the battery using the *Changing the Battery in the Digital Multi-Day Max/Min Thermometer Field Guide*.

Questions for Further Investigations

Which season has the greatest range of temperatures? Why?

How does the soil temperature range vary with soil depth?

What are the latitudes and elevations of other GLOBE schools with soil temperatures similar to yours?

What soil temperatures signal a new growing season in your area, as evidenced by grass or forb germination and growth, or budburst on trees or shrubs?

How does soil texture affect soil temperature?

How does soil temperature vary between sunny and cloudy days at your site and at the different depths?

Thermometer Calibration

Lab Guide

Task

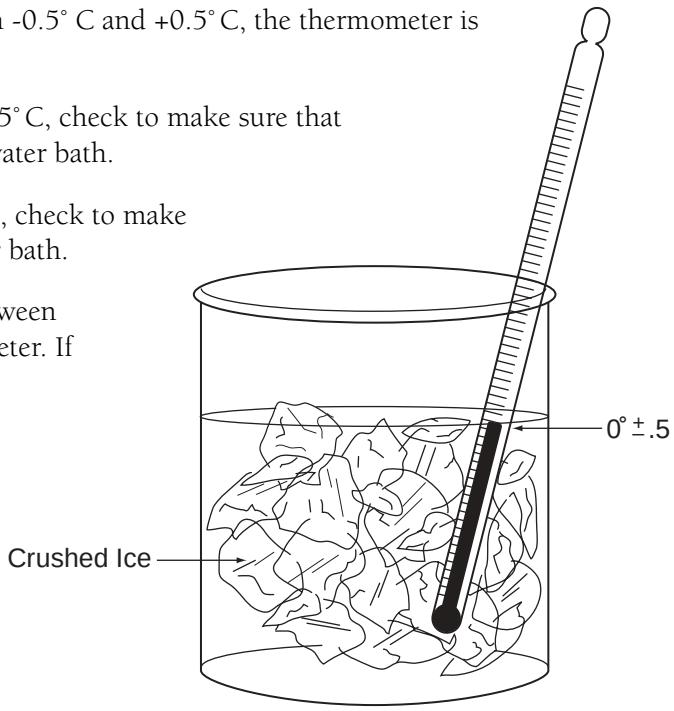
Check the calibration of the calibration thermometer.

What You Need

- ❑ Calibration thermometer
- ❑ Clean container at least 250 mL in size
- ❑ Crushed ice
- ❑ Water (distilled is ideal, but the key is that the water is not salty)

In the Lab

1. Prepare a mixture of fresh water and crushed ice with more ice than water in your container.
2. Put the calibration thermometer into the ice-water bath. The bulb of the thermometer must be in the water.
3. Allow the ice-water bath and thermometer to sit for 10 to 15 minutes.
4. Gently move the thermometer around in the ice-water bath so that it will be thoroughly cooled.
5. Read the thermometer. If it reads between -0.5° C and +0.5° C, the thermometer is fine.
6. If the thermometer reads greater than +0.5° C, check to make sure that there is more ice than water in your ice-water bath.
7. If the thermometer reads less than -0.5° C, check to make sure that there is no salt in your ice-water bath.
8. If the thermometer still does not read between -0.5° C and +0.5° C, replace the thermometer. If you have used this thermometer for measurements report this to GLOBE.



Digital Multi-Day Soil Thermometer Calibration

Field Guide

Task

Calculate the soil sensor correction offsets used to adjust for instrument inaccuracy.

What You Need

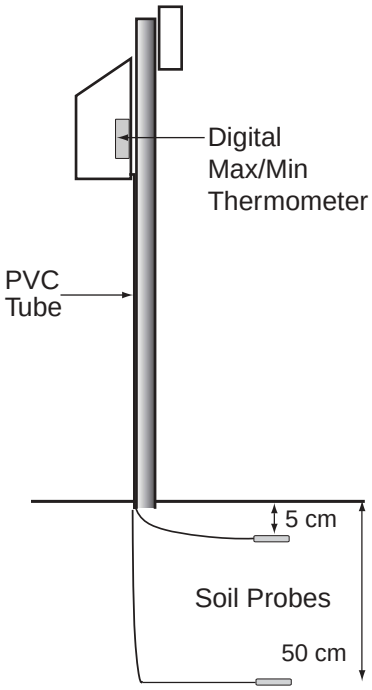
- ❑ Calibration thermometer that has been checked following the instructions in the *Thermometer Calibration Lab Guide*
- ❑ *Digital Soil Thermometer Calibration and Reset Data Sheet*

In the Field

1. Open the door to the instrument shelter and hang the calibration thermometer and the two probes, both 5 cm and 50 cm, in the instrument shelter so that they have air flow all around them and do not contact the sides of the shelter. Close the door to the instrument shelter.
2. Wait at least an hour and then open the door to the instrument shelter.
3. Read the temperature from the calibration thermometer and record it to the nearest 0.5° C on your *Digital Soil Thermometer Calibration and Reset Data Sheet.*
4. Turn on the 5 cm temperature display of the digital multi-day max/min thermometer by pressing the 5 cm sensor ON button (upper left in button cluster)
5. Turn on the 50 cm temperature display of the digital multi-day max/min thermometer by pressing the 50 cm sensor ON button (upper right in button cluster).
6. Read the temperatures reported by the 5 cm sensor and the 50 cm sensor of the digital thermometer and record them on your *Digital Soil Thermometer Calibration and Reset Data Sheet.*
7. Close the cover flap of the digital thermometer and the door of the instrument shelter.
8. Repeat steps 2 to 7 four more times, waiting at least one hour between each set of readings. Try to space out the five sets of readings over as much of a day as possible.
9. Report your calibration data to GLOBE.

Digital Multi-Day Soil Thermometer Installation

Field Guide



Task

Install the digital soil thermometer at your atmosphere or soil moisture study site.

What You Need

- ❑ Drill with 12 mm spade bit
- ❑ Digging tools
- ❑ String or wire ties
- ❑ GLOBE instrument shelter (specifications are given in the *GLOBE Instrument List* in the *Toolkit)*
- ❑ 120 cm length of 2.5 cm diameter PVC pipe (optional)
- ❑ Two pieces of tape
- ❑ A writing instrument

Note: If you are going to be using another digital multi-day thermometer to take air and 10 cm depth soil measurements, try to bury the 5 cm and 50 cm soil probes as close as possible to the 10 cm probe from the other thermometer. If you have not installed that 10 cm probe, this would be a good opportunity to bury all the soil probes in the same hole.

In the Field

1. Mount the digital thermometer housing to the rear wall of your instrument shelter. The housing should be placed so that the digital display may be read easily. If you are out of room on the rear wall, the housing may be left unmounted, lying on the bottom of the shelter.

2. Use two pieces of tape to label the left probe as '5 cm', and the right probe as '50 cm'. Be sure not to stick the tape to the metal tips of the probes.

3. If necessary drill a 12 mm hole, using a drill with a spade bit, in the bottom of the instrument shelter, near the back. Feed the sensor probes through the hole, leaving as much cable as possible inside the shelter. You may wish to feed the sensors through a PVC pipe that will then serve to protect the wires.

4. Bury the probes nearby on the equatorward side (sunny-side) of the instrument shelter mounting post. Data collected from soil in unshaded locations are preferred. Comments in your site definition should include the amount of shade that the soil surface above the probes will experience during a year.

5. Dig a hole to a depth of a little over 50 cm at the chosen location.
6. Push the probe labeled '5 cm' horizontally into the side of the hole at a depth of 5 cm. If needed, use a nail or steel pin, with a slightly smaller diameter than the probe, to pilot an opening for the probe.
7. Push the probe labeled '50 cm' horizontally into the side of the hole at a depth of 50 cm. Again, if necessary, use a nail or steel pin to pilot an opening for the probe.
8. Refill the hole with the soil that you removed (last out, first in).
9. Neatly secure all extra cable using string or wire ties. Keep as much of the excess cable as possible within the shelter.

Digital Multi-Day Max/Min Thermometer Reset

Field Guide

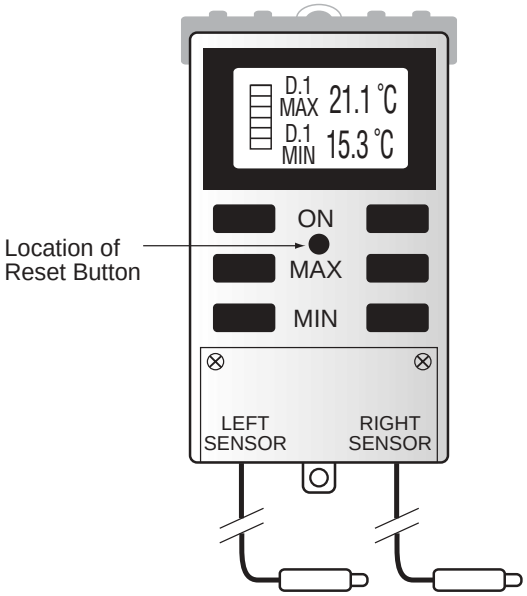
Task

Reset the digital multi-day thermometer to establish the *time of reset,* which serves as the starting and ending time for the 24-hour intervals over which the instrument records maximum and minimum temperatures.

Note: The thermometer should only be reset when it is setup, when the battery is changed, or if your *time of reset* becomes more than one hour from local solar noon.

What You Need

- ❑ Pen or nail
- ❑ *Digital Max/Min Thermometer Calibration and Reset Data Sheet*
- ❑ An accurate watch, GPS receiver, or other device that tells time



In the Field

1. Determine an appropriate *time of reset* that corresponds to the average time of local solar noon for your area. It is important that the *time of reset* is within one hour of local solar noon for every day that you will be taking measurements. If you find that this is not the case, then a new *time of reset* will need to be chosen and the instrument reset.
2. Go to the instrument shelter a little before your desired time of reset and open the instrument shelter and lift the cover flap of the digital max/min thermometer.
3. At your desired time of reset, use a nail or the tip of a pen to press in and release the reset button, located as shown above.
4. The digital display screen will briefly flash and then begin reading the current temperature. The instrument has now been reset. Record the exact time of day, in the *Time of Reset* section of the *Digital Max/Min Thermometer Calibration and Reset Data Sheet*. This is your *time of reset*.
5. Report your *time of reset* and the date to GLOBE in both local and UT time.

Digital Multi-Day Max/Min Soil Temperatures

Field Guide

Task

Measure the daily maximum and minimum soil temperatures, at depths of 5 cm and 50 cm, for the past six days.

What You Need

- ❑ A properly sited instrument shelter
- ❑ A properly calibrated and installed digital multi-day max/min thermometer
- ❑ *Digital Multi-day Soil Thermometer Data Sheet*
- ❑ Pen or pencil
- ❑ An accurate watch or other device that tells time

In the Field

1. Maximum and minimum readings should be taken at least five minutes after your *time of reset*.
2. Open the instrument shelter and the cover flap of the digital max/min thermometer.
3. Record the time and date on your data sheet in both local and UT time.
   Note: GLOBE data entry should be UT time.
4. Turn on the 5 cm temperature display of the thermometer by pressing the 5 cm display ON button (upper left button labeled 'ON').
5. Press the 5 cm sensor MAX button (middle left button labeled 'MAX') **twice.**
   Note: The reading that appears after you press the 'MAX' button once is the highest temp that has occurred since the time of reset, and is not for a full 24-hour period. It should not be recorded.
6. You should see the 'MAX' symbol displayed on the digital display screen to the left of the temperature reading with the symbol 'D.1' displayed above. Record this temperature on your data sheet.
7. Press the 5 cm senor MAX button again. The symbol 'D.2' should now be displayed in place of 'D.1'. Record the accompanying temperature on your Data sheet. Repeat this procedure to record data for as many of the past six days as needed.
8. To record minimum 5 cm temperatures repeat steps 5-7 pressing the 5 cm sensor MIN button (bottom left button labeled 'MIN') instead of the MAX button.
9. For the 50 cm temperatures, repeat the above steps using the 50 cm buttons on the right side and reading from the lower section of the display screen.
10. After all measurements have been taken, close the cover flap of the instrument. It will shut off automatically after a short time. Shut the instrument shelter.

Digital Soil Thermometer Current Temperature

Field Guide

Task

Measure the current soil temperatures, at depths of 5 cm and 50 cm.

What You Need

- ❑ A properly sited instrument shelter
- ❑ A properly calibrated and installed digital multi-day max/min thermometer
- ❑ An accurate watch or other device that tells time
- ❑ *Digital Multi-Day Soil Thermometer Data Sheet*
- ❑ Pen or pencil

In the Field

1. Open the instrument shelter and lift the cover flap of the digital max/min thermometer.
2. Record the time and date on your data sheet.
3. Turn the 5 cm temperature display on by pressing the 5 cm sensor ON button (upper left rubber button labeled 'ON') on the front of the instrument casing.
4. The current 5 cm temperature will now be shown in the upper section of the digital display. Record this temperature on your data sheet.
5. For 50 cm measurements, repeat the above steps using the 50 cm display ON button (upper right button labeled 'ON') and read the value from the lower section of the display screen.
6. After all measurements have been taken close the cover flap of the instrument. It will shut off automatically after a short time. Close the instrument shelter.

Digital Multi-Day Soil Thermometer 5 cm Sensor Error Check

Field Guide

Task

Check that the 5 cm soil sensor is working properly.

What You Need

- ❑ Soil probe thermometer from *Soil Temperature Protocol*
- ❑ *Digital Multi-day Soil Thermometer Calibration and Reset Data Sheet*

In the Field

1. Calibrate a soil probe thermometer following the *Calibrating the Soil Thermometer Lab Guide* of the *Soil Temperature Protocol*.
2. Open the door to the instrument shelter.
3. Select a place about 15 cm from the location of the soil temperature probes.
4. Measure the soil temperature at a depth of 5 cm at this spot following the *Soil Temperature Protocol*.
5. Record this temperature in the '5 cm Soil Sensor Error Check' section of your *Digital Multi-day Soil Thermometer Calibration and Reset Data Sheet*.
6. Turn on the soil temperature display of the multi-day max/min thermometer by pressing the soil sensor ON button (upper left button).
7. Read the temperature reported by the soil sensor of the digital thermometer and record it in the '5 cm Soil Sensor Error Check' section of your *Digital Multi-day Soil Thermometer Calibration and Reset Data Sheet*.
8. Close the cover flap of the digital thermometer and the door of the instrument shelter.
9. Repeat steps 2 to 8 four more times, waiting at least one hour between measurements.
10. Report these data to GLOBE. The GLOBE archive will determine if you need to dig out the soil sensors and recalibrate them following the *Digital Multi-Day Soil Thermometer Calibration Field Guide*.

Changing the Battery in the Digital Multi-Day Max/Min Thermometer

Field Guide

Task

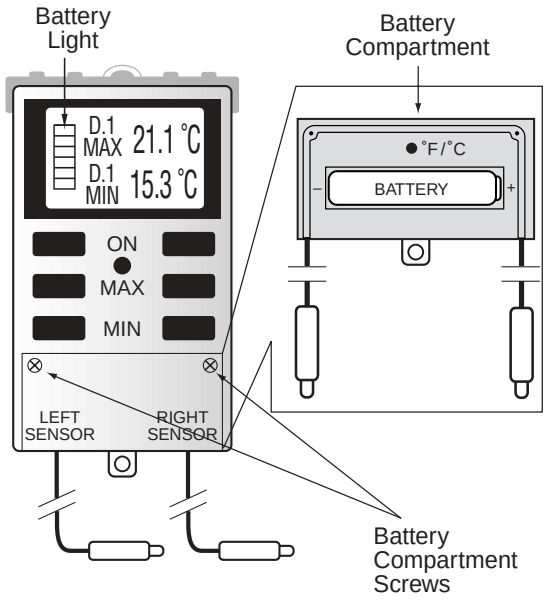
Change the battery in the digital Max/Min Thermometer.

What You Need

- ❑ A new AA-size battery
- ❑ A small Phillips head screwdriver

In the Field

1. The battery is in the battery compartment in the lower section of the instrument casing.
2. Remove the two little screws located at the upper corners of the compartment cover and lift off the cover.
3. Change the battery, taking care to ensure correct polarity (negative end of battery contacting the spring).
4. Replace the compartment cover and secure with the two screws.



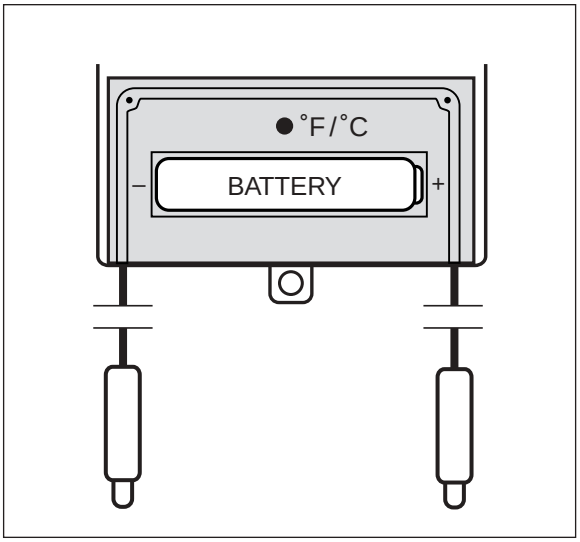
5. Recalibrate the sensors following the *Digital Multi-Day Soil Thermometer Calibration Field Guide*.
6. Reset the instrument using the *Digital Multi-Day Max/Min Thermometer Reset Field Guide*.

Frequently Asked Questions

1. What should I do if my digital max/min thermometer is reading temperatures in degrees Fahrenheit instead of Celsius?

You can change the units by pressing a small button located in the battery compartment. Open the battery compartment following the instructions given in the *Changing the Battery in the Digital Multi-Day Max/Min Thermometer Field Guide*. You should see a small round button, marked °F/°C (see figure below). Turn on at least one of the sensors and press this button. You will see the measurement units change from Fahrenheit to Celsius. Close the battery compartment. Be sure always to have your instrument in Celsius mode when taking GLOBE measurements!

Figure SO-MU-2: Multi-Day Digital Max/Min Thermometer Battery Compartment with cover removed.



2. What if I find that my time of reset is no longer within one hour of local solar noon?

For your minimum and maximum temperature readings to be valid it is necessary for the *time of reset* to be within one hour of local solar noon. Reset your instrument using the *Digital Multi-Day Max/Min Thermometer Reset Field Guide* as close as possible to the time of local solar noon (preferably within 15 minutes).

3. If I miss reading my maximum and minimum temperatures, can I still get the readings the next day?

The max/min temperatures stored in the instrument are updated every 24 hours at the *time of reset*. Therefore, these temperature values can be collected anytime from about 5 minutes after the *time of reset* on the desired day until 5 minutes before the *time of reset* on the next day. If you wait until after the time of reset on the 7th day, one day's data will be lost. However, if they are read on the next day, care must be taken to match correctly temperatures read from the instrument to the corresponding days. Maximum and minimum temperatures displayed along with the 'D.1' symbol on the instrument display screen correspond to the current day when readings are being taken after *time of reset* (as recommended) and to the previous day when readings are being taken before the *time of reset*. See the following tables for clarification:

Readings taken AFTER time of reset (as recommended).

Digital Display			
Symbol:	D.1	D.2	D.3
Reading Corresponds to 24-hours Ending:	Today	Yesterday	2 days ago

Readings taken BEFORE time of reset

Digital Display			
Symbol:	D.1	D.2	D.3
Reading Corresponds to 24-hours Ending:	Yesterday	2 days ago	3 days ago

4. Can I read the thermometer in the morning before the time of reset?

If the thermometer is read in the morning, at least 5 minutes before the *time of reset*, it is possible to read the max/min temperatures for the past six days. However, the max/min temperatures for the current day cannot be read.

5. When I first press a MIN or MAX button, the instrument displays a reading which I am not supposed to record; what is this reading?
The reading displayed when you press a MIN or MAX button for the fist time is the minimum or maximum temperature for the on-going 24-hour period. Since this period is not finished, the reading may not be the final maximum or minimum temperature for the 24 hours. While it is not valid data that you report to GLOBE, it can be used to for your own inquiry purposes.

6. How does the digital thermometer work?
The thermometer works by measuring the change in current running through a constant-voltage circuit in which the sensor probe serves as a resistor. As the temperature of the sensor changes, it's electrical resistance changes. The change in current in the circuit is inversely proportional to the change in the sensor's resistance as described by Ohm's Law which explains that current is equal to voltage divided by resistance. So by measuring the current going through the circuit, and knowing the voltage, it is possible to calculate the resistance of the sensor. This is done by the instrument, which then reports the probe temperature corresponding to that level of resistance.

Soil Investgation

Digital Multi-Day Soil Thermometer Calibration and Reset Data Sheet

School Name: _____ Study Site: _____

Observer Names: _____

_____

Calibration

Thermometer Readings						
Reading Number	Date (yy/mm/dd)	Local Time (hour:min)	Universal Time (hour:min)	Calibration Thermometer Readings (˚C)	Digital 5 cm Sensor Readings (˚C)	Digital 50 cm Sensor Readings (˚C)
1						
2						
3						
4						
5						

Time of Reset

Note: The thermometer should be reset only when it is first setup, after the battery is changed, or if the time of local solar noon drifts to more than one hour from your *time of reset.*

Date: _____ Local time (Hour:Min) _____ Universal time (Hour:Min) _____

Was the reset due to a battery change?_____

5 cm Sensor Check

Thermometer Readings					
Reading Number	Date (yy/mm/dd)	Local Time (hour:min)	Universal Time (hour:min)	Soil Probe Thermometer Readings at 5 cm (˚C)	Digital 5 cm Sensor Readings (˚C)
1					
2					
3					
4					
5					

Soil Investigation

Digital Multi-Day Soil Thermometer Data Sheet

School Name: _____ Study Site: _____

Observer Names: _____

_____

Date: Year _____ Month _____ Day _____

Local time (Hour:Min)_____ Universal time (Hour:Min) _____

Your *Time of Reset* in universal time (Hour:Min): _____

Current Temperatures

5 cm soil temperature (°C): _____

50 cm soil temperature (°C): _____

Maximum, Minimum Temperatures

Do not read the thermometer within 5 minutes of your *time of reset.*

	Label on Digital Display Screen					
	D1	D2	D3	D4	D5	D6
Maximum 5 cm Temperature (°C)						
Minimum 5 cm Temperature (°C)						
Maximum 50 cm Temperature (°C)						
Minimum 50 cm Temperature (°C)						
If you are reading thermometer AFTER your *time of reset:* Correspond to 24-hour Period Ending:	Today	Yesterday	Two days ago	Three days ago	Four days ago	Five days ago
If you are reading thermometer BEFORE your *time of reset:* Correspond to 24-hour Period Ending:	Yesterday	Two days ago	Three days ago	Four days ago	Five days ago	Six days ago